April 2022

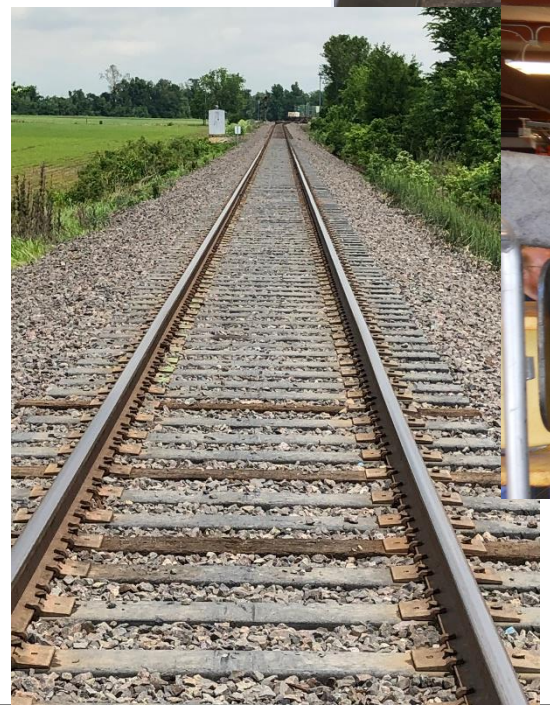
UPRR Composite Tie History & In-Track Experience

How do we move forward?

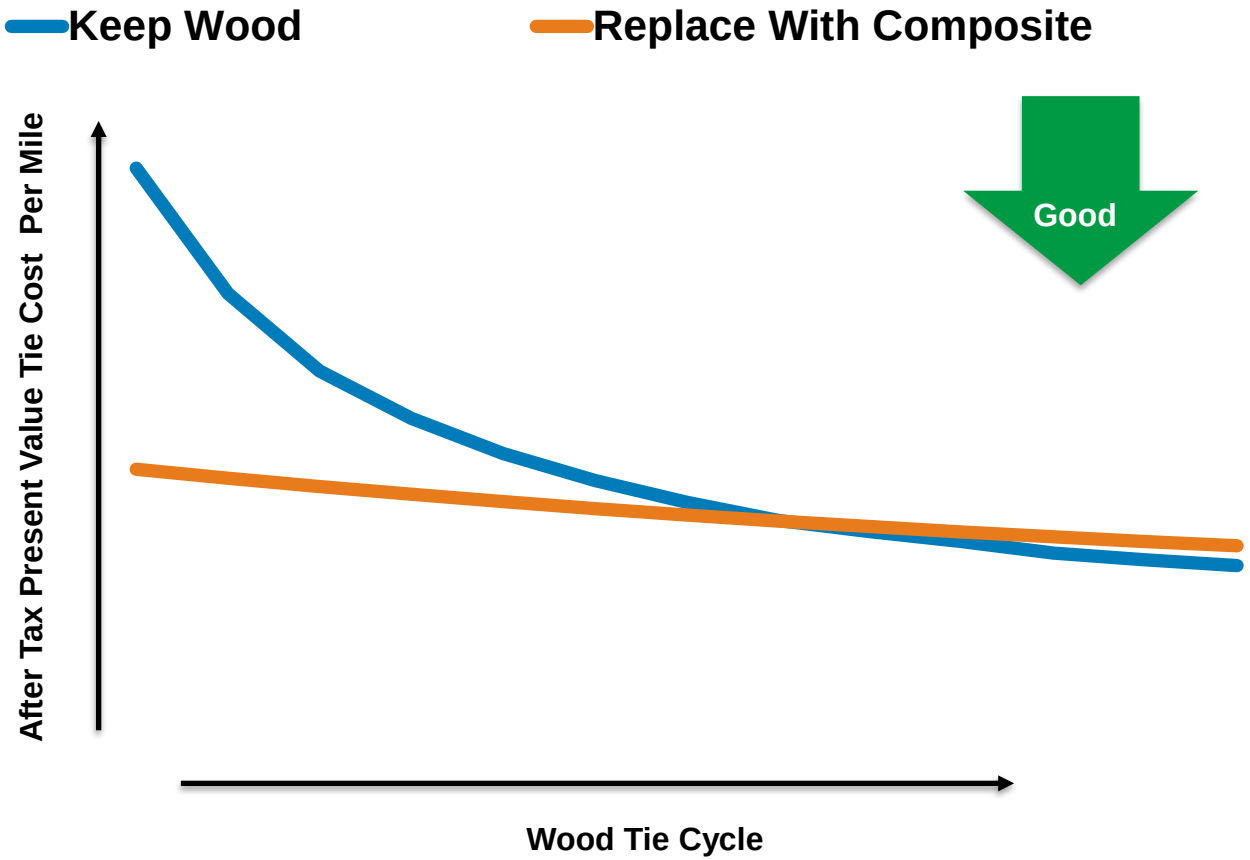
Mike Gilliam – Sr. Dir. Assessment & Technology

Union Pacific Composite Tie Journey

- Since the late 90's UP has been testing multiple vendors EPC ties from all over the world
- From late 90's to 2017 UP experience has been the same – not good
- 2017 UP took a different approach
- Cautious optimism



Composite Tie Economics



Cost model compare life cycle of wood vs. composite tie

Shorter wood tie cycle is where composite tie value is

Break even changes significantly as composite tie price increases

Successful Installation Example

Stamps, AR Installation 2002

- Over 1 BGT since Installation
- No wood tie intervention for two cycles
- Makes hardwood available for other projects
- Disposal cost do not exist

Failure Drivers

Center Breaks – Bending Stress

Spike Area – Concentrated Loading

What Makes A “Good” Tie

Primary Considerations

- Strength
- Flexibility
- Consistency (Quality)
- Detailed Installation procedure

Secondary Considerations

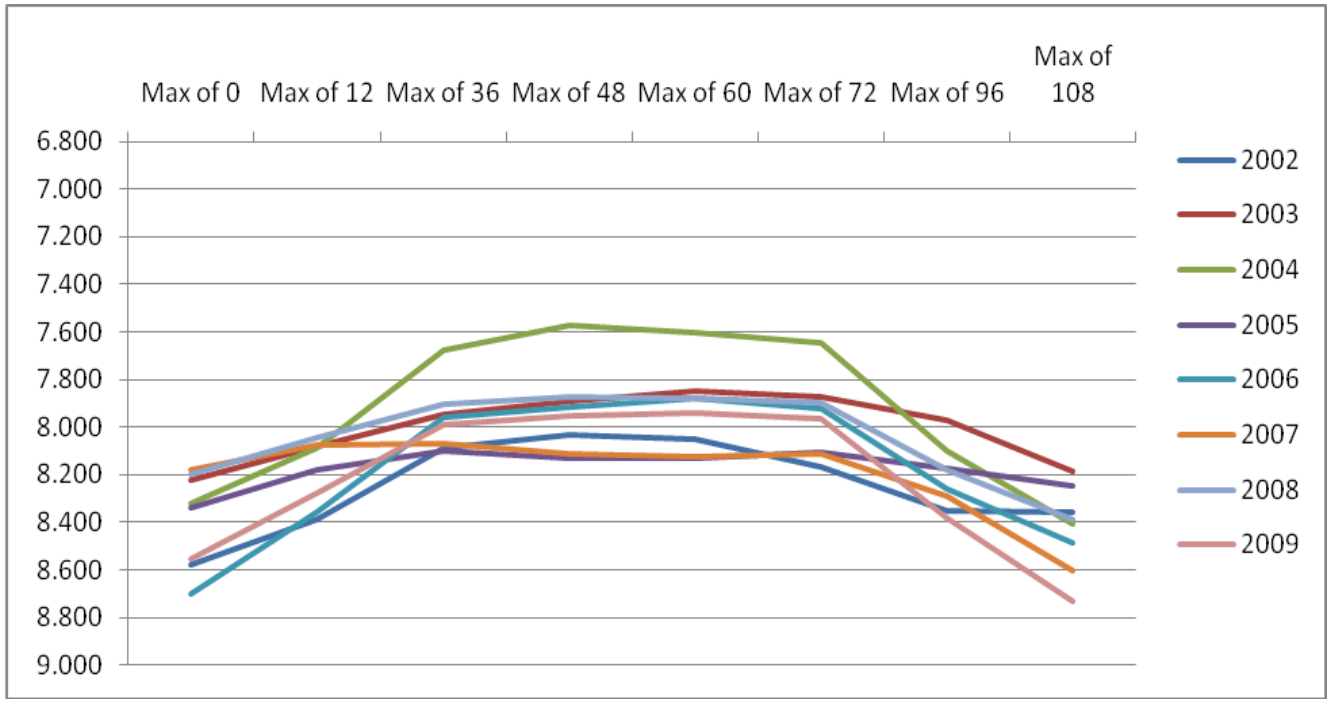
- Thermal Conductivity
- Thermal Expansion

Dictated largely by base polymer selection (Poly-ethleyne)

Solved with good/continued process control by vendor, and rigorous testing prior to market.

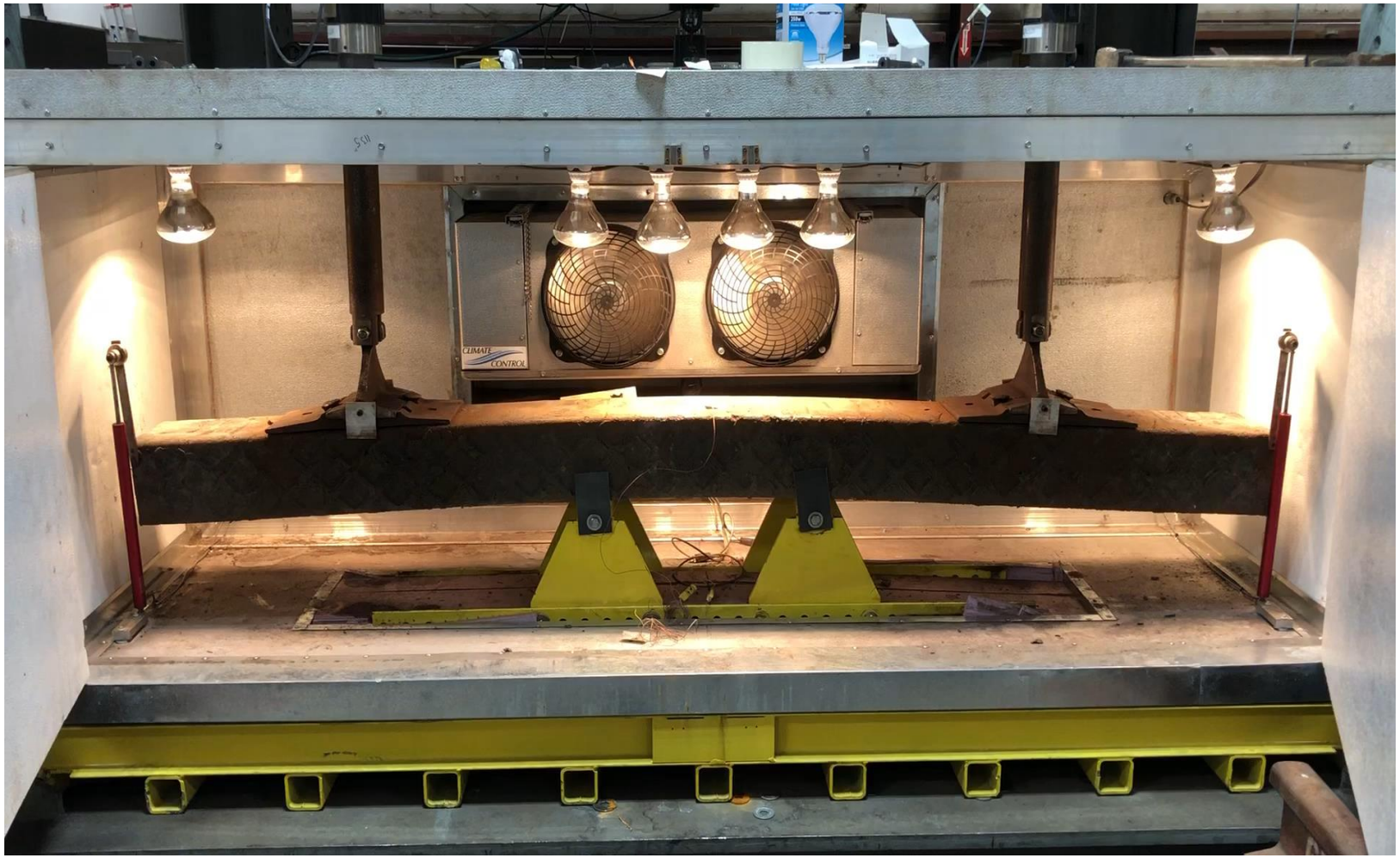
Deflection Observations

- Clear evidence that in-situ deflection of 1/2” or greater is highly common
- Time since last surfacing cycle has a direct correlation to deflection – However accumulated tonnage does not
- Worst case scenario shows deflection of 1” – 1.5” can be expected
- Deflection increases directly with time
- Thermal deflection can be greater than mechanical deflection

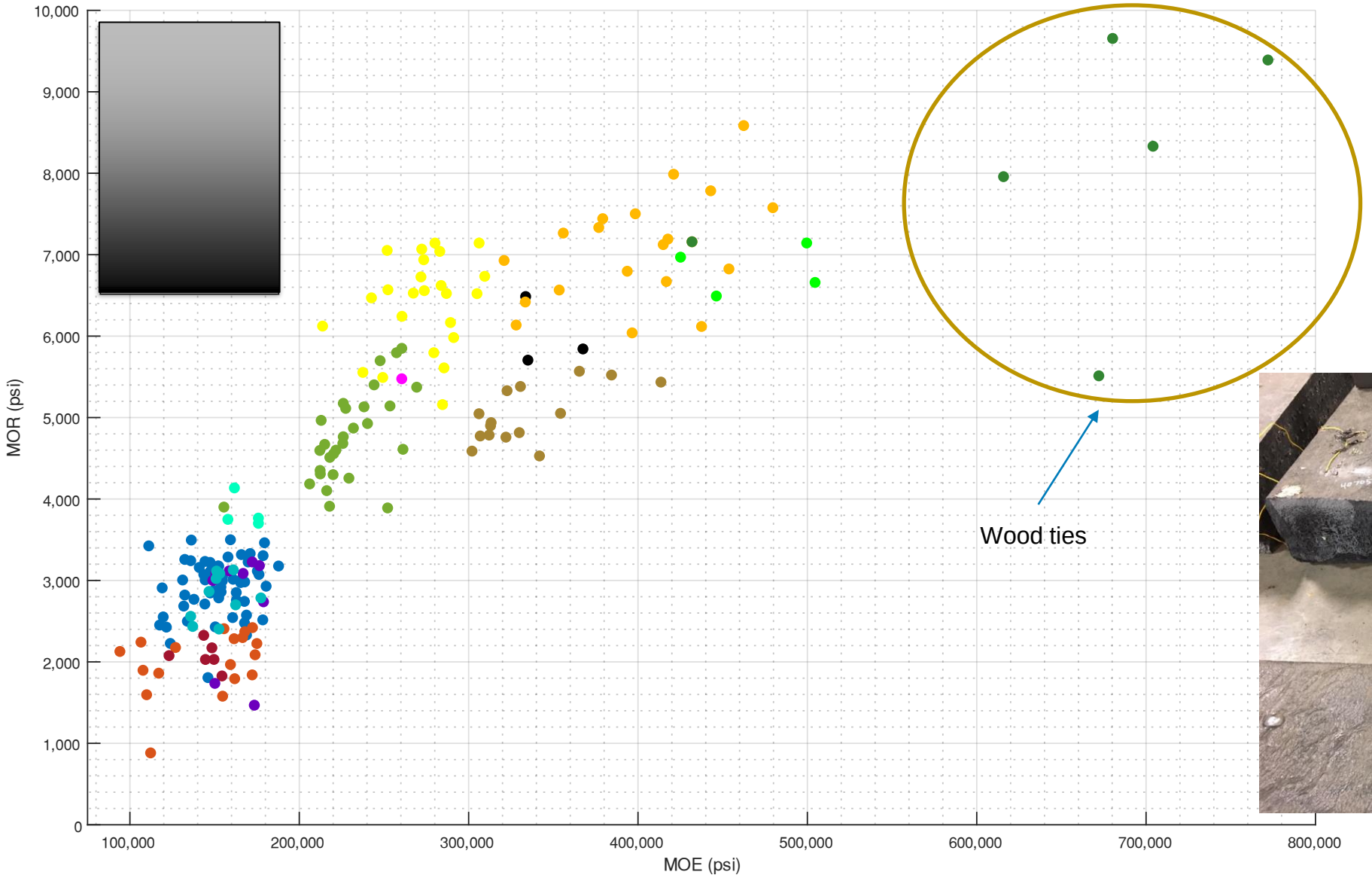


Temperature Chamber Deflection Test

- Designed to mimic extreme field loading (Thermal and Mechanical)
- Center bound tie
- Monitor:
  - Bending strain
  - Tie temp (top/bottom)
  - End deflection
  - Rail seat deflection
  - Rail seat load



MOE/MOR Test Data

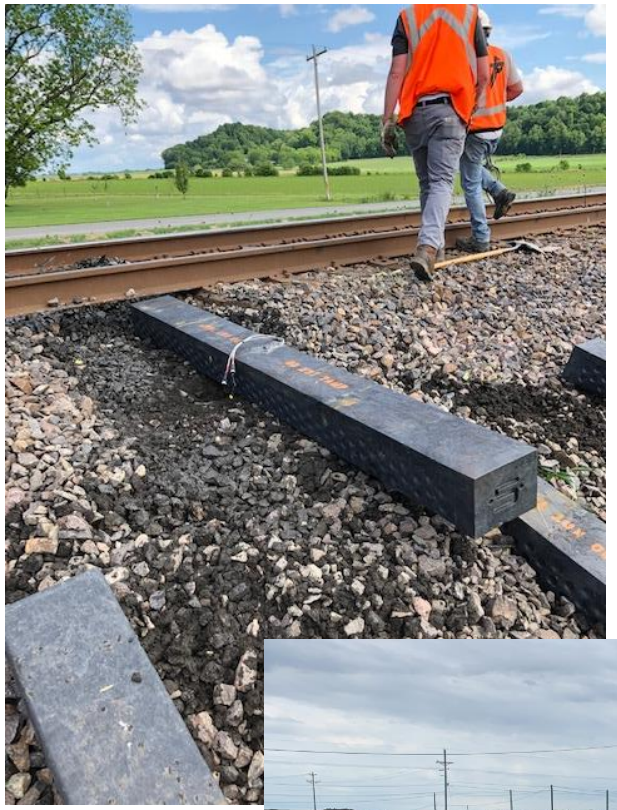


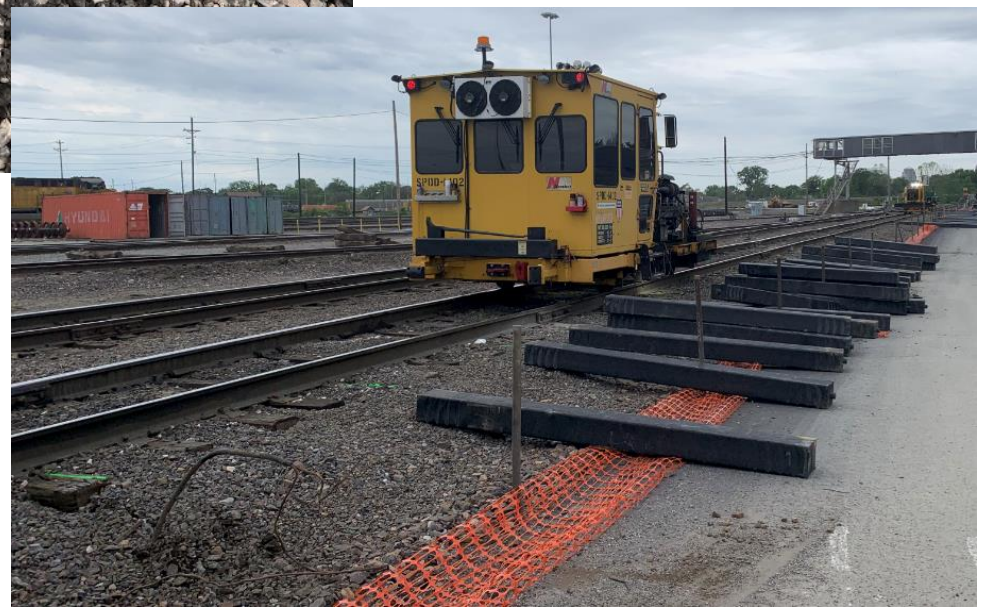
Recent Composite Ties

How do we ensure consistency?

Current Observations

- Chester Sub 1500+ ties (200 MGT)
  - Mixed install, very controlled
  - Instrumented ties
  - Small section of cold spiked, all others pre-drilled
  - Two vendors
    - 1 failure center break
- Little Rock Sub 4500 ties (80 MGT)
  - 100% predrilled
  - Controlled install
  - One vendor
    - 1 failure installation issue
- A&S Yard 450 ties (2021 Install)
  - Yard grade ties
  - Muddy location & sharp curve
  - Mixed fastener types
    - 4 failures in muddy subgrade





In Track Tests (Chester Sub)

- 2 suppliers ties instrumented
- Install date roughly May 20th, 2020
- Constant readings of center bending strain & top & bottom tie temp
- Installed roughly 1500 ties, very controlled installation

What Does the Future Hold

- UP believes there is a future for EPC ties
- Quality materials, tight QC & strict install procedures will determine success
- Economics will continue to be a driving force on quantities
- Special track work, bridges, tunnels

MxV Rail (formerly TTCI)
Pueblo, Colorado USA
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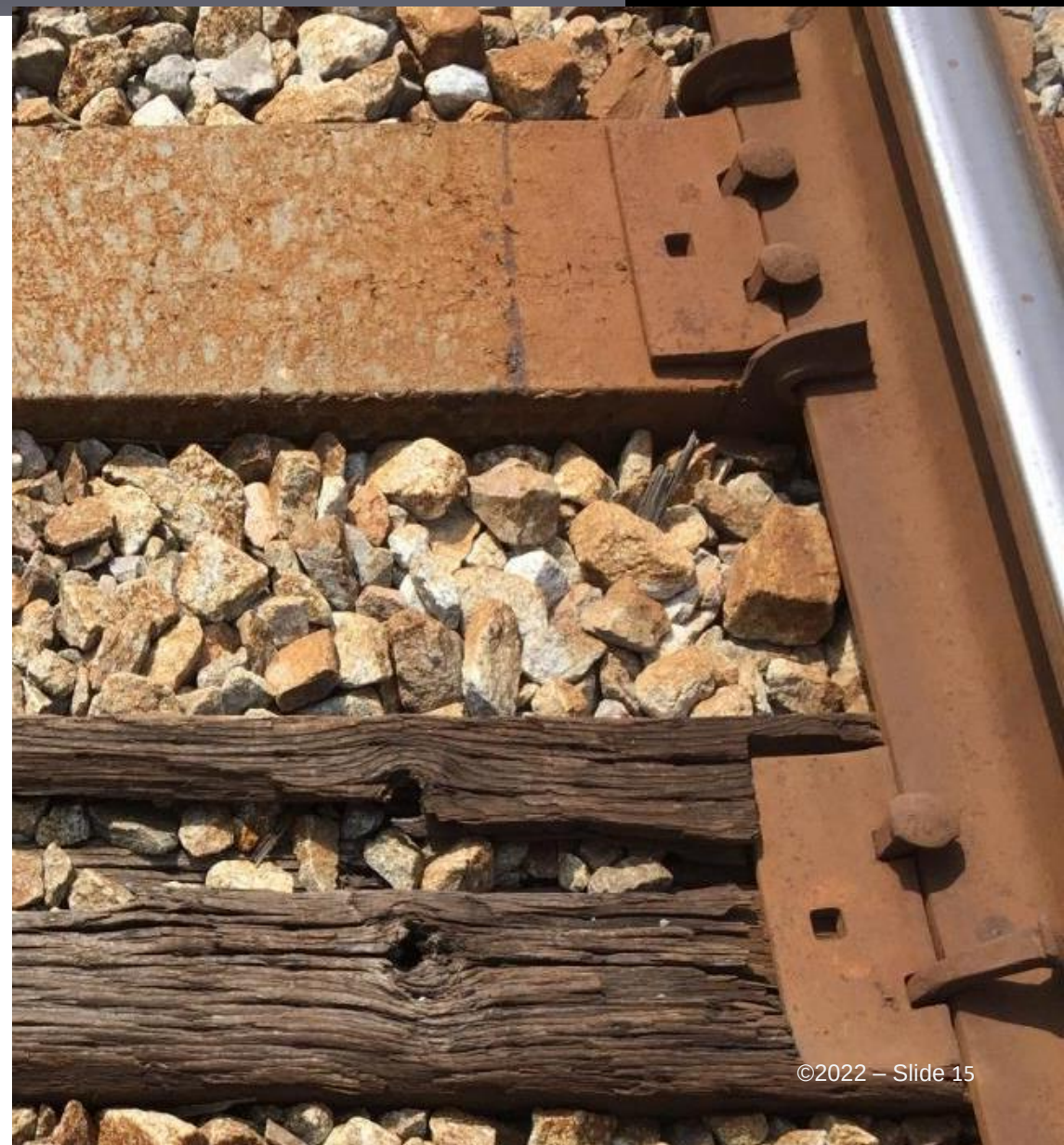
FRA Track & Railroad
Workplace Safety Symposium
April 5-7, 2022, St. Louis, MO

Composite Ties: Performance, Design and Testing Guidelines

Yin Gao
Senior Engineer II

Overview

- Background, motivation, industry perspective and practices (UP)
- Overview of MxV Rail's EPC tie research program
- Performance of composite ties
- Test guidelines and recommendations
- Summary

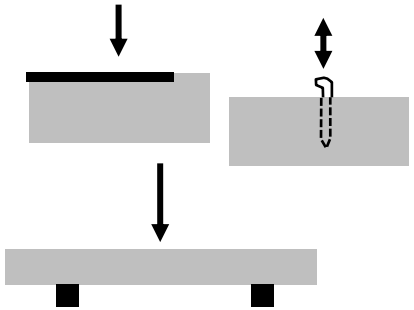


AAR and FRA Research on Composite Ties

- **MxV Rail supports industry needs through**
  - In-track testing and measurements
  - Laboratory testing
  - Modeling effort

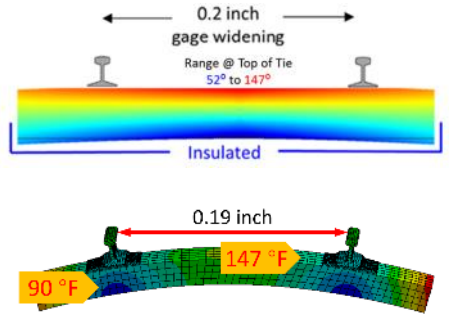
Test Zones at FAST and in Revenue Service

Qualification Lab Testing

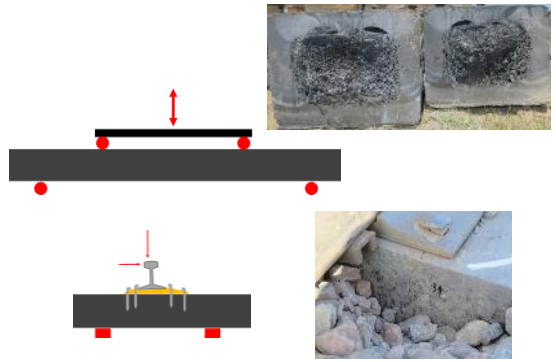


Field Measurements

Modeling



Fatigue Test Development



In-Track Performance Evaluation

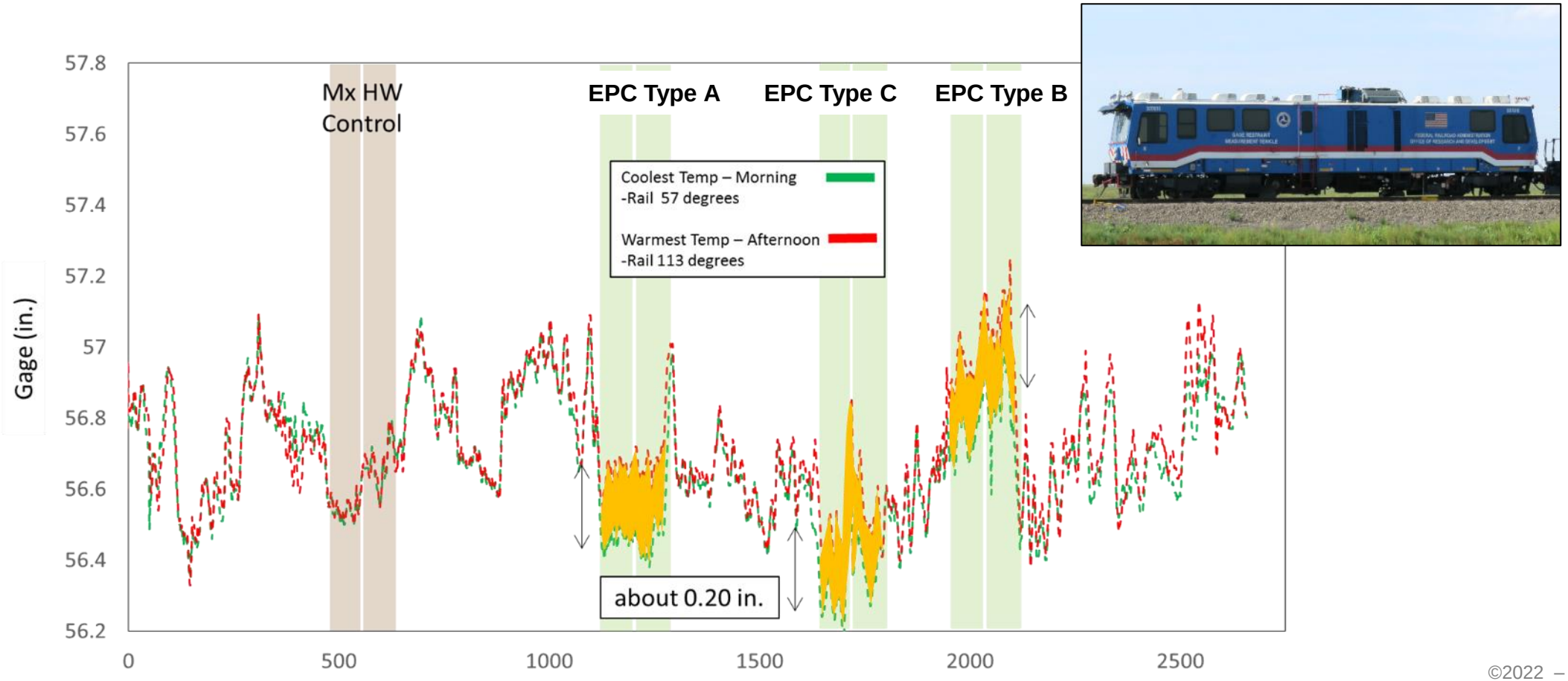
- **FAST and revenue service experience**
  - Four types of EPC ties since 2015
    - Two main failure modes were identified
  - Minimal plate cutting
  - In-track failure rates and modes inconsistent

Two Failure Modes Identified

- **Spike hole cracking and center cracking**
  - Typically, not seen on wood ties
  - Fourteen percent of the EPC ties experienced these two failure modes within 218 MGT at FAST
  - In-track measured bending strains were far less than tie ultimate strength, indicating a fatigue failure

Effect of Temperature on Track Gage

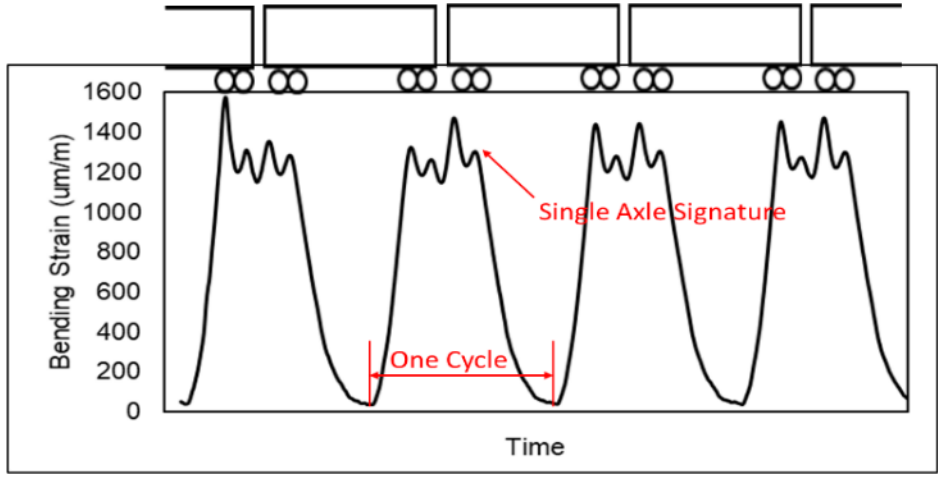
- **Static Gage Measurement at FAST by FRA T-18**
  - 0.2-inch gage widening due to temperature change in EPC tie zones only



In-track Loading Environment

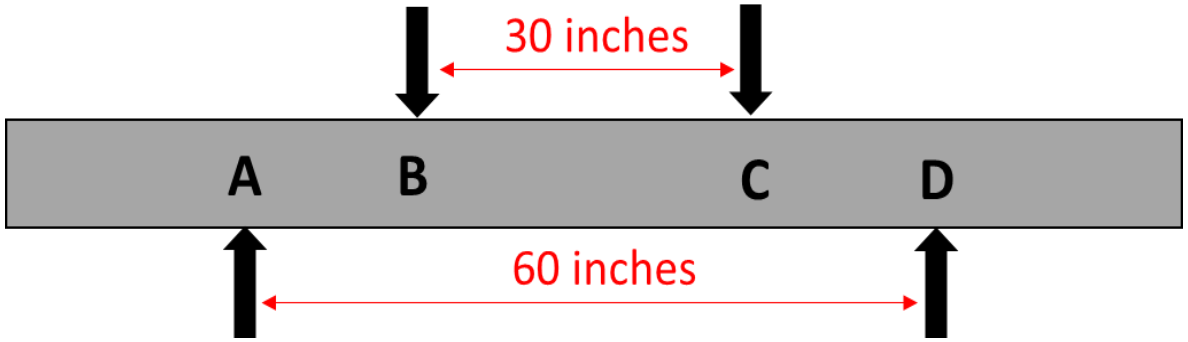
- **In-track center bending strain**
  - Strain gages on the top surface of ties
  - Data collected in revenue service and at FAST

Tie Type	MOE (ksi)	Avg. Center Strain (με)
FAST Measurements		
A	212	1701.5
B	133	1778.5
D	405	1471.9
Revenue Service Measurements		
A	212	1338.8
C	181	1364.2

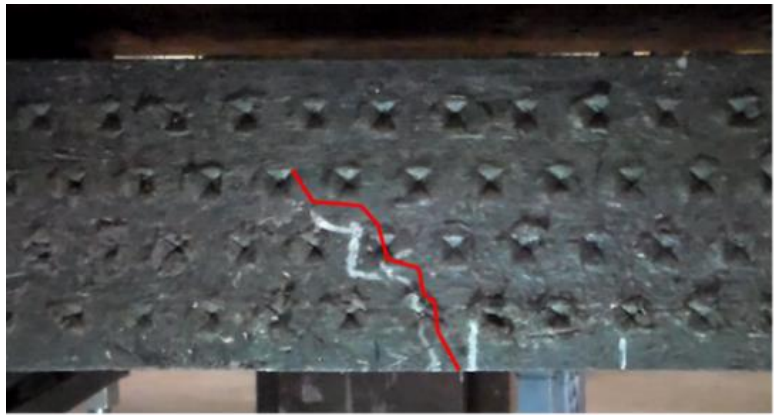


Proposed Laboratory Fatigue Test

- **Test Setup**
  - Four-point bending test to generate constant bending moment in the middle section of the tie
  - Clamps at four span supports to eliminate creep effect
  - 1.5 million fatigue cycles



Test Results and Analysis

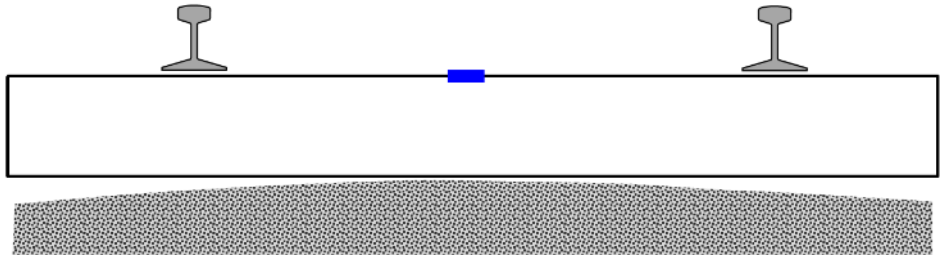


- **Nine EPC ties were tested with the test setup**
  - Two broke with a center crack similar to that observed in track
  - Successfully identified EPC ties with internal defects without overloading good quality ties

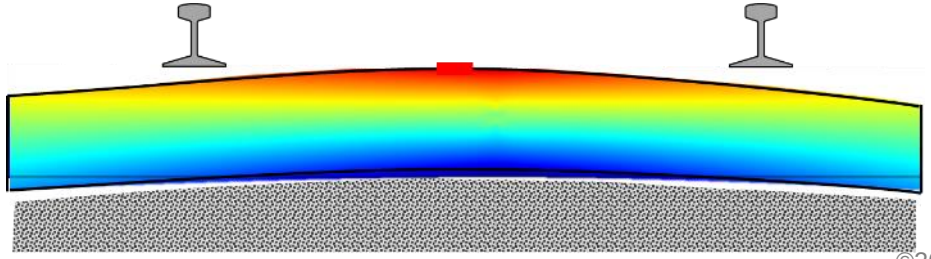
Thermal Effects on EPC Ties

- **Temperature increase and temperature differential in ties caused gage widening**

8am - Tie Temp 50 degrees

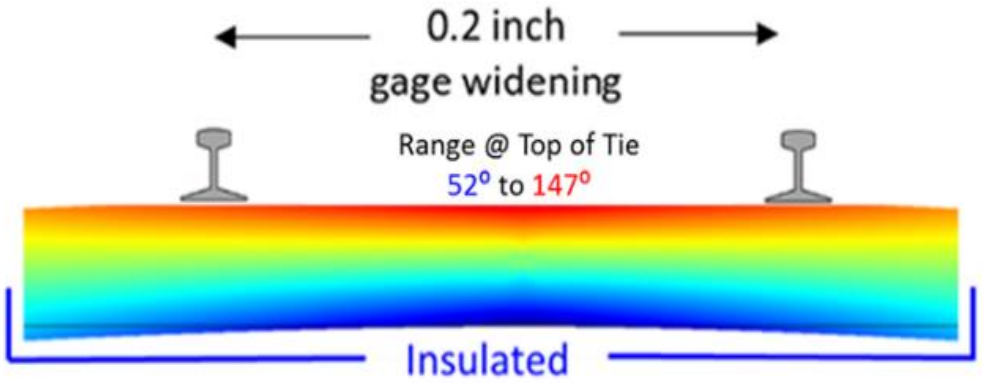


3pm – Tie Temp 90 degrees

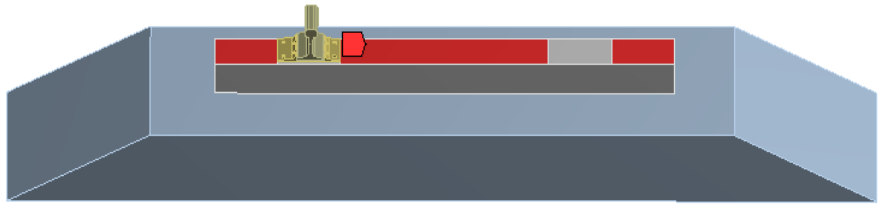


Simulation of Thermal Effect

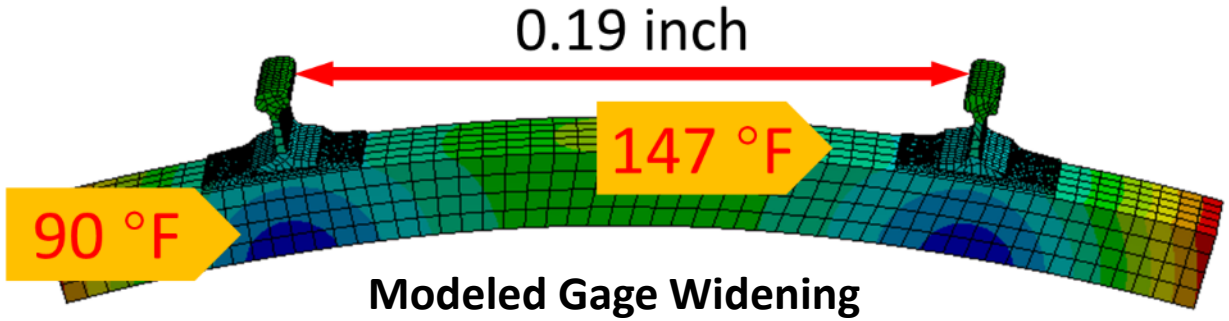
- **Finite Element Model**
  - Steady-state thermal analysis on a single-tie model
  - Modeling results matched the gage widening measured in track



Field Measured Gage Widening



Temperature Measurements	
Time	2:00 pm
Ambient	**90 °F**
Top Tie	**147 °F**
Side/End Tie	**90 °F**



Modeled Gage Widening

More Modeling Cases

- **Baseline case (Case 2): A typical tie and a typical temperature swing**
- **Lowest, average, AREMA maximum coefficient of thermal expansion**
- **Normal vs. extreme temperature conditions**

Modeling Cases	Coefficients of Linear Thermal Expansion (10^{-5} in/in/°F)	Ambient Temp. (°F)	Tie Surface Temp. (°F)	Gage Widening (inch)
Case 1	3.5	90	147	0.1
Case 2	**5.0**	**90**	**147**	**0.19**
Case 3	7.5	90	147	0.26
Case 4	3.5	50	147	0.12
Case 5	5.0	50	147	0.21
Case 6	7.5	50	147	0.29

Allowable Gage Widening in FRA § 213

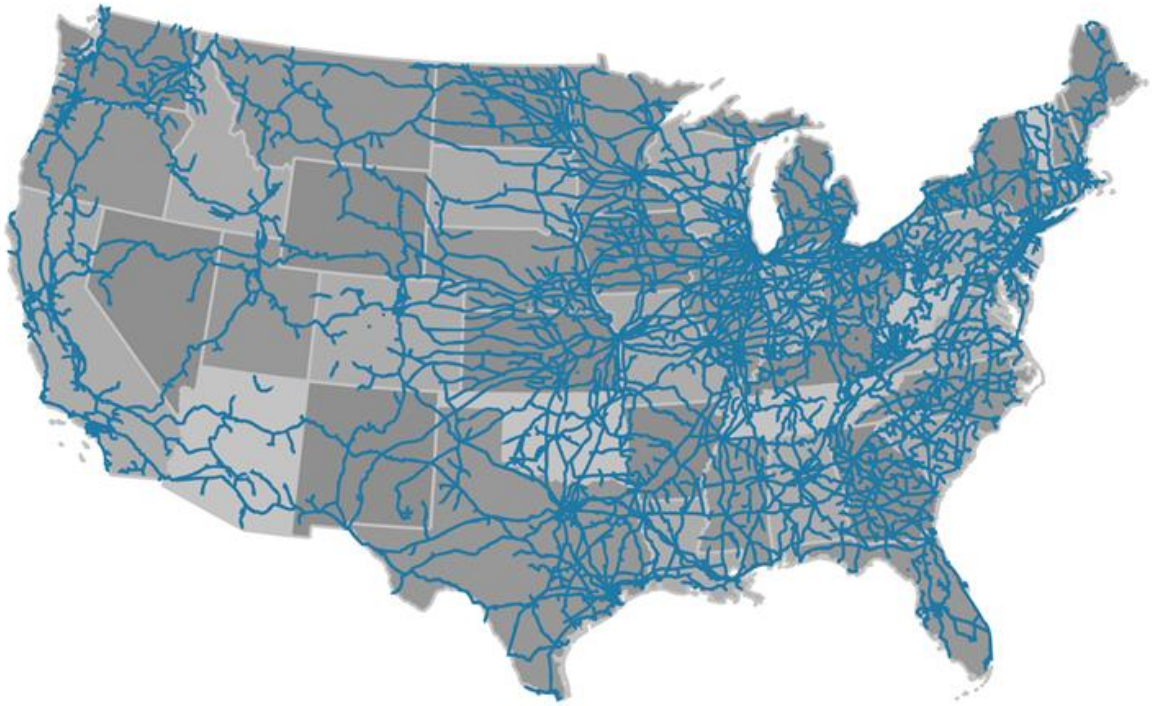
Track Class	Gage Widening
Excepted Track	1 3/4 in.
Class 1	1 1/2 in.
Class 2 and 3	1 1/4 in.
Class 4 and 5	1 in.
Class 6 and above	3/4 in.

Summary

- **Industry expectation: EPC ties provide one-to-one replacement of wood ties**
- **In-track performance showed failure modes unique to EPC ties**
- **A laboratory fatigue test proposed to identify underperforming EPC ties**
- **Simulation of thermal effects confirmed field observations of gage widening of EPC due to temperature increase**

Acknowledgements

- Federal Railroad Administration
- Class I Railroads
- EPC Tie Suppliers
- Research Team at MxV Rail




Thank you
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